U.S. Department of the Interior
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Shallow Lake Limnology Monitoring Protocol
Central Alaska Network National Parks and Preserves, Alaska

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Important Note: This sampling protocol consists of this Protocol Narrative and the following Standard Operating Procedures (SOPs):

SOP 1: Field Season Preparation

SOP 2: Delineation of Study Region

SOP 3: Acquisition of Recent Imagery

SOP 4: Image Rectification

SOP 5: Delineation of Shallow Lakes

SOP 6: Locating Hot Spots of Lake Change

SOP 7: Sampling Frame and Lake Selection

SOP 8: Continuous Lake Monitoring

SOP 9: Training Personnel

SOP 10: Field Trip Mobilization

SOP 11: Daily Field Startup

SOP 12: Using the Trimble GPS

SOP 13: Installing Benchmark and Establishing Sampling Transect

SOP 14: Relocating Lake and Sampling Locations

SOP 15: Photo-documentation

SOP 16: Water Level Determination

SOP 17: Water Chemistry Field Data and Sample Collection

SOP 18: Vegetation Field Sampling

SOP 19: Aquatic Invertebrate Field Sampling

SOP 20: Preserving Plant Samples

SOP 21: Field Processing of Water Chemistry Samples

SOP 22: Field Trip Demobilization

SOP 23: Macroinvertebrate Processing and Identification

SOP 24: Data Management

SOP 25: Data Analysis (TO BE DEVELOPED)

SOP 26: Reporting (TO BE DEVELOPED)

SOP 27: After the Field Season

SOP 28: Revising the Protocol

SOP 29: QA/QC

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Shallow Lake Limnology Monitoring Protocol

Narrative

I Background and Objectives

Introduction

The Central Alaska Network (CAKN) is part of the National Park Service (NPS) Inventory and Monitoring Program. It is composed of three national park units: Wrangell-St. Elias National Park and Preserve, Denali National Park and Preserve, and Yukon-Charley Rivers National Preserve.

The Inventory and Monitoring Program is the result of the National Parks Omnibus Management Act, which was passed by Congress in 1998. This act directs the National Park Service “to establish baseline [resource] information and to provide information on the long-term trends in the condition of National Park System resources.” To accomplish this formidable task, the NPS has grouped parks into 32 networks which are characterized by their ecological similarities. Four of these networks are in Alaska.

The Central Alaska Network is vast: its three parks together contain over 8.8 million hectares (21.7 million acres) and span an area that is 650 km from east to west and 650 km from north to south. Based on area, the Central Alaska Network represents 25% of all the land in the National Park Service system. Yet despite this immense coverage, these three parks contain natural resources — both physical and biological — that are similar in many respects. Perhaps the most significant shared feature is the integrity of their ecological systems. These parks provide the space and the time to see and understand natural processes that are occurring at great spatial and temporal scales.

The primary goal of the Central Alaska Network is to build a holistic database that will allow detection of change across the ecosystems of the network — specifically, to detect change in the ecological components of the Network parks, and in the relationships among those components. The Network is currently conducting baseline inventories of selected resources, and is developing and prioritizing a list of “vital signs” for long-term monitoring.

Rationale for Selecting This Resource to Monitor

When people think of Alaskan Parks they visualize spectacular mountain ranges and massive glaciers, big clear lakes and large glacial rivers, pristine wilderness where vast ecosystems remain intact and unmodified by human hands. Rarely do they think of the large flat expanses of land that predominate in much of the state. But it is here in the flat lands where large expanses of wetlands perform critical ecological functions that support large populations of mammals, waterfowl and furbearers. And it is here where people still rely on these food resources to survive. Yet it is in these seemingly pristine systems where scientists are seeing the first signs of climate change that appear to be related to global warming and where they predict the greatest impacts will occur. It is for these reasons that the Central Alaska Network has chosen to monitor several vital signs associated with shallow lake ecosystems (lakes <5m deep) for the National Park Service Inventory and Monitoring Program.

Traditional water quality monitoring programs emphasize monitoring the physical and chemical properties of water. Monitoring the physical and chemical properties of water is an excellent means by which to track human modifications, such as industrial effluent or human sewage, to watersheds because water in lakes and streams carries with it the chemical signature of its watershed. Monitoring water quality in pristine ecosystems is somewhat more complicated in that contaminants or human modifications may not be known, present, or easily detected by physical or chemical measures of water quality. Because many of the wetlands found in CAKN are relatively free of direct human modification we have designed a somewhat unconventional water quality monitoring program that has four basic elements: 1) traditional measures of the physical and chemical properties of water, 2) water quantity, 3) physical structure of shallow lakes, and 4) internal biological assessments including vegetation and macroinvertebrates.

Park vital signs are selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park. Vital signs to be monitored in shallow lake ecosystems include: water quality, water quantity, vegetation and macroinvertebrates. These vital signs were chosen because they represent important physical, chemical and biological elements of these poorly understood ecosystems and because they are essential to the maintenance of healthy wetland ecosystems. Here we provide the detailed rationale for choosing shallow lake ecosystems as the platform for monitoring these elements and discuss why these vital signs were chosen.

Shallow lakes are an excellent choice for monitoring these vital signs in the Central Alaska Network (CAKN) because they are extremely abundant. Nearly 47% of the state of Alaska is classified as wetland (Hall et al. 1994) and shallow ponds and lakes are a major wetland feature. In the CAKN well over 25,000 shallow lakes and ponds are distributed across the landscape. Not only are shallow lake systems abundant, they are an excellent choice for monitoring changing conditions because they are microcosms; small theatres where the ecological interactions of organisms and their environment can be more easily tracked because they are easy to sample, they have distinct boundaries (as compared to other wetland ecosystems), and they provide relatively easy opportunities for field experiments. Working in an ecosystem where changes are easy to track will enhance our ability to document trends and to provide early warnings of impending threats.

Shallow lakes, and their associated vital signs, serve a diverse array of ecological functions. The interactions of physical, biological and chemical components of a shallow lake, such as soils, water, plants and animals, enable the ecosystem to perform vital functions such as water storage; storm protection and flood mitigation; shoreline stabilization and erosion control; groundwater recharge; groundwater discharge; water purification through retention of nutrients, sediments, and pollutants; and stabilization of local climate conditions, particularly rainfall and temperature (Mitsch and Gosselink, 1986). Wetlands, of which shallow lakes are one type, are among the world's most productive environments and provide a wide variety of ecological benefits (Mitsch and Gosselink, 1996). They are cradles of biological diversity, providing the water and primary productivity upon which countless species of plants and animals depend for survival. Due to high nutrient concentrations they often support high rates of primary production by phytoplankton as well as littoral vegetation. Their shallow nature and high rates of primary production allow development of large beds of macrophytic vegetation that provide critical habitat to macroinvertebrates and rearing areas for waterfowl, shorebirds and fishes. Because they are so productive and support diverse groups of plants and animals, shallow lakes in the CAKN are particularly important to the people who hunt and trap within the boundaries of the Parks. These people rely on shallow lakes for harvesting subsistence resources such as moose, waterfowl, and furbearers. Because of their remoteness, modern protected status. and the resulting relative lack of human influence on them, the shallow lake ecosystems of the CAKN parks also have enormous value as references of background conditions for monitoring efforts on other more developed lands in the region (MacCluskie and Oakley 2003; personal communication with Laura Eldred, AK DEC).

Very little is known about the physical, chemical or biologic structure of shallow lake ecosystems in CAKN, despite their ecological importance. This lack of knowledge regarding these systems is somewhat surprising since they are critical to subsistence users in Alaska and because several lines of evidence suggest these systems are declining. Currently 11 bird species that depend on boreal forest wetlands have been listed as species of concern by the North American Bird Conservation Initiative (NABIC) (2004) because their populations have been slowly declining. All of these bird species are found in wetlands throughout the CAKN (Table 1) and the majority nest and rear their young here. Wetlands in the CAKN are part of the northwestern interior forest conservation unit (BCR4) outlined in the NABIC, which covers most of central Alaska and the Yukon Territory. This conservation effort is dedicated to promoting and advancing integrated bird conservation in North America. Ducks Unlimited has ranked BCR4 as number three of the 25 most important and threatened waterfowl habitats on the continent.

Table 1. Distribution of bird species of concern found in wetlands in the parks of the Central Alaska Network.

Bird Species	Denali National Park and Preserve	Wrangell-St. Elias National Park and Preserve	Yukon-Charley Rivers National Preserve
Greater Scaup	X	X	X
Lesser Scaup	X	X	X
White-winged Scoter	X	X	X
Black Scoter	X	X	
Surf Scoter	X	X	X
Short-eared Owl	X	X	X
Rusty Blackbird	X	X	X
Olive-sided Flycatcher	X	X	X
Blackpoll Warbler	X	X	X
Lincoln's Sparrow	X	X	X
Horned Grebe	X	X	X

It appears that not only are waterfowl populations declining in the boreal forest, but shallow lake ecosystems appear to be disappearing as well. Over the past 20 years much concern has been expressed regarding the apparent decline in water level in shallow lake ecosystems in Alaska. Many scientists, native elders and local people have noticed a drying trend in shallow lake ecosystems throughout the parks in the CAKN. Empirical evidence in Alaska corroborates this trend and shows a dramatic decrease in lake surface area, likely due to global climate change (Riordan pers. comm. 2004; Yoshikawa et al. 2003). In subarctic interior Alaska, increases in warmth and dryness from the 1970s to present have occurred with decreased tree growth (Lloyd and Fastie 2002) and temperature-induced drought stress (Barber et al. 2000). Reduction of surface water area has also occurred in some areas of central Alaska during this period (Figure 1). Shallow lakes in the CAKN are particularly sensitive to global climate change because the hydrologic cycle here is closely tied to seasonal snow cover and permafrost, which interact with topography and geology to create and maintain vast wetlands characterized by the presence of shallow lake and pond systems.

Several studies in Alaska have linked lake drying with permafrost degradation (Yoshikowa and Hinzman 2003, Jorgensen et al. 2001). In subarctic Alaska, freshwater wetlands undergo seasonal inundation during spring snowmelt (Ford and Bedford 1987). Ice-rich permafrost prevents percolation of surface water to groundwater and maintains these ponds despite relatively low rates of precipitation. Much of the Central Alaska Network lies within the zone of discontinuous permafrost and many areas within this zone have been dramatically impacted by permafrost degradation related to global climate change. Extensive permafrost degradation has been documented in western Canada (Bielman et al. 2001), Russia (Pavlov 1994), China (Ding 1998), Mongolia (Shakuruu 1998) and interior Alaska (Ostercamp et al. 2000). The discontinuous permafrost zone is particularly susceptible to degradation because the ice is very near the melting temperature and so is easily degraded by slight changes in temperature (Luthin and Guymon 1974).

When permafrost degrades, one of two things often happens. Where thawed ground sinks below water level, new wetlands are formed. In upland areas, however, drainage is often enhanced, converting wetlands to a drier ecosystem. Under either condition, permafrost degradation changes the hydrologic cycle. Hydrology is considered to be the single most important factor in the establishment and maintenance of shallow lake ecosystems (Mitsch and Gosselink 2000) and changes in climatic conditions that influence the availability of water in these systems will dramatically affect the structure and function of wetland communities, especially the plants and animals dependent upon them.

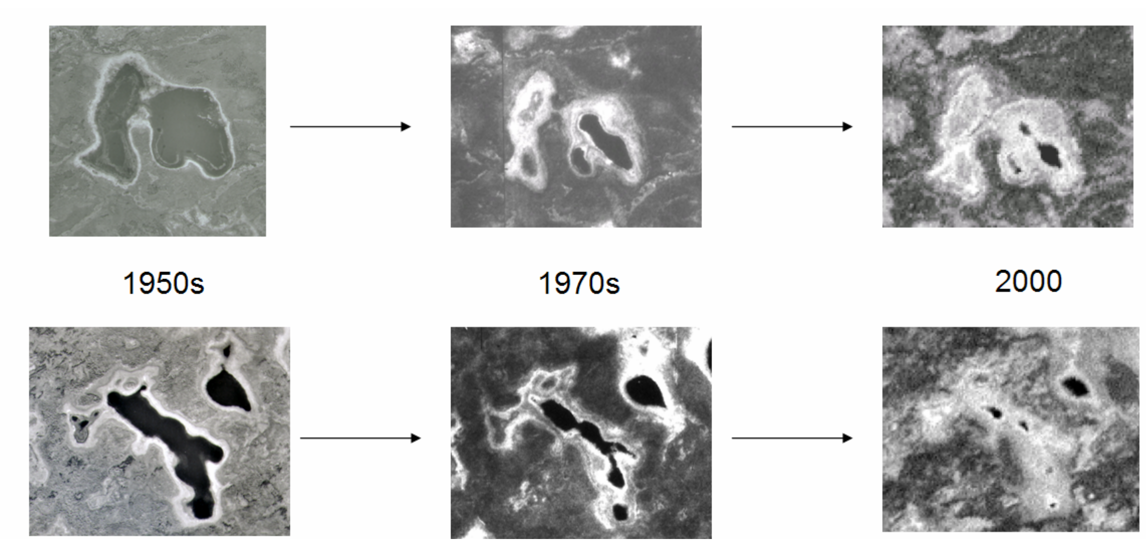

Figure 1. Examples of reduced lake surface water area in the Yukon Flats National Wildlife Refuge, an area approximately 50 km northwest of Yukon-Charley Rivers National Preserve.

The objective of the vital signs monitoring program is characterizing and determining trends in the condition of park natural resources. Trend information is essential to assess the effectiveness of management and restoration activities, and to provide early warning of impending threats. Currently scientists are detecting and monitoring trends in climate data in Alaska. A report from the Alaska Regional Assessment Group for the U.S. Global Change Research Program (1999) documents the climate of the past century and projections for the next. This research showed that Alaska has already experienced a series of dramatic changes in the past 60 years and that interior Alaska, where the CAKN network is located, has experienced the greatest change. It has warmed about 4 ºF, on average, since the 1950's, 7 ºF in the interior in winter (Chapman and Welsh 1993; Weller et al. 1998), with much of this warming occurring in a sudden regime shift about 1977 (Weller and Anderson 1998). The majority of the state has also become wetter, with a 30% average increase in precipitation between 1968 and 1990 (Groisman and Easterling 1994). The growing season in Alaska also has lengthened by 14 days (Keyser et al. 2000). These climate changes have already been linked to changes on the landscape such as increased melting of glaciers, warming and thawing of permafrost, and retreat and thinning of sea ice (Echelmeyer et al. 1996, Sapiano et al. 1998, Lachenbruch and Marshall 1986, Ostercamp 1994, Osterkamp and Romanovsy 1996, Wadhams 1990, Cavalieri et al. 1997, Serreze et al. 2000, Kabil et al. 1999, Dowdeswell et al. 2000). Furthermore, climate models predict continued strong warming in Alaska reaching 1.5-5.0 ºF by 2030, and 5-18 ºF by 2100, with the strongest warming in the interior and north, and with greatest warming during the winter months.

Continued precipitation increases are also projected; 20-25% increases are projected in the north and northwest, and decreases are expected along the south coast of Alaska. These authors also suggest that increased evaporation from warming is projected to more than offset the increased precipitation, making soil drier in most of the state. Changes in temperature and precipitation will undoubtedly impact seasonal stream-flow and the ability of the environment to store and release water from snowpack, glaciers, and lakes. All of the above parameters will be affected by a continuing trend towards a warmer climate, and this in turn will likely alter disturbance regimes; the most import being fire (Flannigan et al. 2001, Chapin 2003).

Anthropogenic global climate change and the subsequent effects on fire frequency and intensity as well as potential changes in the distribution of permafrost and hydrologic regime may lead to more rapid changes in the size, abundance or distribution of aquatic resources on the landscape. For these reasons there is mounting concern regarding the stability of shallow lake ecosystems in the Central Alaska Network. It is with these concerns in mind that we propose to monitor shallow lakes and the associated vital signs. We expect the shallow lake monitoring program will provide the broad-based, scientific information necessary to help make sound management decisions and support research, education, and public awareness regarding the parks that is required of the Inventory and Monitoring program.

Rationale for Selecting These Parameters to Monitor

One of the primary purposes of the vital signs monitoring program is to provide park managers across the country with information to help them better manage park ecosystems. These managers are confronted with complex and challenging issues that require a broad-based understanding of park resources as a basis for making decisions, working with other agencies, and communicating with the public to protect park natural systems and native species. Subsistence issues and global climate change are two of the most complex and difficult issues park managers in Alaska must deal with. It is the responsibility of park managers to know and understand what changes are occurring in their parks and it is the job of the monitoring program to provide information regarding trends in natural resources. We have selected 4 aspects of shallow lakes and ponds to assess the condition of shallow lake ecosystems that we believe will enable park managers to make these difficult decisions. These are: (1) water quantity, (2) water chemistry, (3) vegetation, and (4) macroinvertebrate communities. Below we outline the rationale for the selection of these parameters for the Water Quality Vital Sign.

Water Quantity

A critical component to the mission of the inventory and monitoring program is to have knowledge of the current condition of natural resources in each park. Knowing what natural resources occur in each park and understanding how and why they are changing is extremely important to this program. One of the measurable objectives of the shallow lake monitoring program is to track changes in water quantity on the landscape scale. The primary means by which we will track trends in water quantity is to monitor shallow lakes using remote sensing. Current and future conditions can be monitored using satellite imagery or aerial photography. Tracking long term trends in the number and surface area of shallow lakes will improve our understanding of the impact of a reduced water balance at the landscape level. By examining the trends inside and outside of wildfire burns, the impact of wildfire on aquatic systems can also be assessed at the landscape scale.

To test the remote sensing techniques we have established a cooperative agreement with Dr. Dave Verbyla with the University of Alaska Fairbanks to determine the most appropriate platform for remote sensing. The tools used to measure changes in water quantity on the landscape are are presented in SOP 2: Delineation of Study Region; SOP 3:, Acquisition; SOP 4:, Image Rectification; SOP 5:, Delineation of ; and SOP: Locating Hot Spots of Lake Change. These SOPs have been included because they provide important background and methodology regarding how this portion of the monitoring program will be conducted. These methodologies will be subject to intensive review and modification once the appropriate platform has been selected and a strategy for monitoring the entire network is designed.

A variety of ancillary data will help us understand and track inter-annual variation in water quantity. The two primary data sets that will allow us to track this variability are annual estimates of total precipitation and water level. Network concern regarding climate change prompted the CAKN to invest a great deal of effort developing the climate vital sign. This program has installed several weather stations throughout the network. These weather stations will provide critical information regarding the hydrologic cycle including estimates of total precipitation and temperature. Snow monitoring efforts which include measurements of snow depth along snow courses, snow markers and establishing at minimum one Nipher station to get high quality data regarding winter precipitation are particularly important to shallow lake monitoring because these data provide critical information regarding the primary source of water recharge to these systems. The network is also developing a permafrost monitoring protocol that will help explain shallow lake dynamics related to permafrost change. Together these data will help the CAKN explain why shallow lakes are changing.

Monitoring water level is an essential tool to help the CAKN evaluate water quantity changes on the landscape scale. Shallow lake ecosystem dynamics are largely driven by changes in water level (Mitsch and Gosselink 1986). As the water volume of lakes is reduced, the physical, biological and chemical characteristics of the system could change substantially. With reduced volume, shallow lakes may freeze to the bottom during cold winters, eliminating fish species. Other substantial impacts could include changes in the length of the growing season, wind-induced mixing, gas transfer, underwater light availability, water chemistry, and phytoplankton dynamics (Vincent et al. 1998, Adrian et al. 1999). Water level can also have profound impacts on many wetland components including, decomposition and biogeochemical cycling, contaminant concentration and bioavailability, plant species composition and primary production, and direct and indirect impacts on the distribution and abundance of other organisms living within the wetland.

Water Chemistry

Basic chemical properties of water can be extremely informative. Many water quality characteristics are relatively uniform within an ecoregion and result from regional, watershed, geologic, basin and hydrologic characteristics. These measures can help us understand the types of water bodies found in our parks. Water quality variables such as alkalinity, conductivity, turbidity, color and dissolved organic carbon can tell us a great deal about the chemical signature of the water in a lake basin and can be useful as a monitoring tool to indicate changing conditions. Monitoring many of these chemical constituents is made easy and relatively cost effective because of the accurate multi-meter probes available today.

Factors such as light, water chemistry, oxygen (O_2) availability, temperature, and pH can control biotic communities. These factors can also indicate anthropogenic effects on the system. Parameters selected for monitoring in the CAKN and the reasons for their selection are given in Table 2.

Table 2. Water quality parameters to be monitored.

Water Quality Parameter	Rationale for sampling
Temperature*	Changes over time can indicate warming/climate change, closely related to oxygen solubility and decomposition rates
Dissolved Oxygen (DO)*	Important for understanding biogeochemical cycling, lake productivity, and distribution of biota
pH*	Measure of hydrogen ion activity
Specific conductance*	Measure of water purity
Total nitrate (NO_3) plus nitrite (NO_2)	Trophic state
Total Kjeldahl nitrogen (TKS)	Trophic state
Total phosphorus (TP)	Trophic state
Chlorophyll-a	Measure of algal biomass – trophic state
Apparent color	Related to light availability – lake metabolism
Secchi depth	Measure of light availability – lake metabolism
Alkalinity	Buffering capacity of water – changes have been related to permafrost degradation
Hardness	Measure of calcium and magnesium

* represent core water quality parameters required of WRD.

Structure and Composition of Littoral Vegetation

Perhaps the most conspicuous feature of a lake margin wetland is the distinct pattern of aquatic vegetation that rings the open water zone in response to seasonal patterns of immersion and emersion. Because wetland plants are so sensitive to slight changes in immersion time and soil moisture, or more explicitly oxygen conditions, they have been extensively used to identify and classify wetland ecosystems (Cowardin et al. 1979). Not only are aquatic plants useful for classifying wetlands but they are considered keystone species in the littoral zone where they determine the structure and function of the wetland ecosystem and form the basis of the food chain (Mitsch and Gosselink 1986). Structurally wetland vegetation provides critical habitat to epiphytic bacteria, and some species of algae, periphyton, macroinvertebrates, amphibians, and fish. Aquatic macrophytes have repeatedly been shown to support higher invertebrate diversity and abundance when compared to adjacent non-vegetated zones (Dvorak and Best 1982, Iversen et al. 1985). In the littoral zone, vegetation not only provides a substrate and cover to organisms but is also the primary contributor to the detrital pathway by way of leaf litter inputs (Mitsch and Gosselink 1986).

Aquatic plants also have profound impacts on the chemical signature of water in wetlands; they remove nutrients by uptake and accumulation, and they can act as a nutrient pump by moving compounds from the sediment and into the water column (Mitsch and Gosselink, 1986). They also frequently improve water quality by removing nutrients, metals and other contaminants from the water and sediment.

Plants are excellent indicators of wetland condition for many reasons, including their relatively high levels of species richness, rapid growth rates, and direct response to environmental gradients and change (EPA 2001). Plants are found in all wetlands and sampling techniques are well developed for both emergent and to a lesser extent submergent species. Plants also respond to human-related alteration of the environment in such a way that the change in the plant community can easily be quantified. There is a high diversity of wetland plants, and each species has a different tolerance to human disturbance. The ecological tolerances are well known for many species. Aquatic plants are virtually all immobile so they are effective indicators of both acute and chronic stress occurring at that location. Finally plant taxonomy is well known and with adequate training most observers can accurately conduct field surveys.

Of particular importance to the CAKN is our ability to detect changes in plant species composition in relation to changes in hydrology. A great deal of research has been conducted on the relationship between hydrology and plant community dynamics. Wetland plants have been shown to respond to water depth (Spence 1982, Grace and Wetzel 1982, 1998), water chemistry (Ewel 1984, Pip 1984, Rey Benayas et al. 1990, Rey Benayas and Scheiner 1993) and flow rates (Westlake 1967, Lugo et al. 1988, Nilsson 1987, Carr et al. 1997). Aquatic plants are also known to respond to changes in nutrient regime (Pip 1984, Kadlec and Bevis 1990), light, sediment loading and turbidity (Vander Valk 1981, 1986; Sager et al 1998; Wardrop and Brooks 1998), toxic contaminants and metals, and salinity. Typically, macrophytes respond more slowly to environmental changes than do phytoplankton or zooplankton; as a result of the longer response time, plants are likely to be better integrators of overall environmental condition. For these reasons we believe monitoring vegetation will be an excellent means by which to track changing conditions in shallow lake ecosystems.

Macroinvertebrate Community Composition

Macroinvertebrates are the most frequently used group in bioassessments of aquatic ecosystems (Hawkes, 1979; Hellawell, 1986; Abel, 1989; Oswood et al. 1991; Rosenberg and Resh, 1993; Davis et al, 1996) because they have several advantages over other biota. Some of the most significant benefits of monitoring macroinvertebrates (Table 3) are that they are ubiquitous, they have relatively low mobility (Rosenberg and Resh, 1993) compared to organisms like fish and aquatic birds, and they are moderately long-lived. As a result they are continuously exposed to the habitat conditions of their local environment and can reflect cumulative impacts to an aquatic system over a relatively long period of time. They generally occur in sufficient variety and abundance that they are easy to collect. They are present year-round and are often abundant. Many macroinvertebrate species respond in a predictable way to environmental changes. The biochemical and behavioral responses of these organisms have been studied and are well documented at the individual, population and community levels (Johnson et al. 1993), making invertebrates excellent indicators of habitat change or degradation. It is also important to understand that they do not respond to all types of impacts (Hawkes, 1979). Macroinvertebrates are themselves important not only as a food resource but as major contributors to global biodiversity. Benthic invertebrates are in constant contact with lake sediments and can therefore reflect influences of pollutants or disturbance. Ecologically they provide a link in the food chain between primary producers (algae) or organic detritus, and fish or birds and are fundamental members of the detrital pathway. Because they are the primary food resource for most fish and some aquatic birds in the CAKN, the diversity and abundance of macroinvertebrate populations is of direct management concern (Oswood, 2001). Finally, they are a cost-effective monitoring tool.

Table 3. Summary of the advantages for monitoring macroinvertebrate populations (adapted from Milner, 2001 and Oswood, 2001).

• They are ubiquitous and generally have low mobility
• They are the primary food resource for fish and some aquatic birds
• Assemblages are diverse, with organisms that have differential sensitivities
• Sampling protocols are well developed, tested, and cost effective
• A variety of assessment methods for data analysis can be employed
• Specific responses have been established for many taxa • They are well suited to experiment studies
• They have close association with sediments which are repositories of nutrients and toxins

By inventorying the species and groups of invertebrates that inhabit shallow lakes, we can evaluate and monitor the ecological health and productivity of the system. Measures of macroinvertebrate population numbers or community composition along with water chemistry and other monitoring parameters, can give detailed information on the health of the ecosystem being monitored. This information, collected over time, will be highly valuable in measuring amount and rates of change within an ecosystem, whether due to natural or human influences. For these reasons we believe monitoring macroinvertebrate populations will provide us with valuable information regarding ecological changes taking place in shallow lake ecosystems. These data will be an effective tool for monitoring trends and detecting changing conditions.

Macroinvertebrates can be found in most habitats of shallow lakes: the substrate (benthic invertebrates), the submerged vegetation, the water column, the water surface, and in vegetated growth at the waters edge. The littoral zone of lakes and ponds supports more diverse assemblage of macroinvertebrates than the sublittoral or profundal zones (Moore, 1981; Wiederholm, 1984). Thus, monitoring for CAKN will be done in the littoral zone of each lake and will sample only macroinvertebrates (as opposed to small invertebrates). Monitoring this community is made easier because well developed and standardized methodologies have been developed, although many of these methods are designed for use in lotic (flowing water), rather than lentic (still water) systems.

Historical Development of Shallow Lake Monitoring

In November of 2001, the CAKN created an aquatic monitoring work group to scope aquatic related issues in the three parks. This group reviewed the basic concerns of each park and used these concerns to direct the monitoring program. In April of 2002 a formal scoping workshop was held to discuss the aquatic issues and to make preliminary decisions regarding aquatic monitoring in the CAKN. At this early stage the aquatic monitoring group decided to split monitoring into two major categories of ponds and streams. These ecosystems were selected for the following reasons:

- Distinct boundaries;
- Great opportunity for integration between terrestrial and aquatic systems;
- Support a diversity of organisms;
- Logistically simpler than larger waterbodies; and
- Well represented in all three parks.

This group also decided to take a community approach to monitoring the physical, chemical and biologic components of lakes and streams rather than monitor individual species. Furthermore, the group decided to take a landscape scale approach to monitoring these systems because very little is known about either of these systems in the CAKN. The group understood and accepted that this approach would sacrifice depth of understanding for breadth.

During 2003, as part of the second phase of the monitoring programs development, the CAKN conducted a pilot study to assess the feasibility of conducting this type of monitoring in the network parks. We conducted preliminary evaluations of macroinvertebrate, littoral vegetation and water chemistry monitoring in Yukon-Charley Rivers National Preserve. Initial evaluations of the pilot data suggest that monitoring shallow lakes in all three parks is feasible. This, combined with management concerns regarding the stability of shallow lake ecosystems within the network, encouraged us to proceed in developing this program.

The pilot study helped us outline several difficulties in sampling shallow lake ecosystems in remote areas of Alaska. The following major concerns were identified:

- choosing an index period,
- designing a vegetation monitoring strategy that deals with variable littoral zone width,
- composite sampling,
- and data comparability with other agencies and organization in Alaska

To remedy these concerns, NPS established a contract with Hart Crowser Inc., an environmental consulting firm, to help develop a protocol and standard operating procedures (SOPs) for sampling physical and chemical properties of water, macroinvertebrates and littoral vegetation. The primary objective of this contract was to carefully review all historic and ongoing research being conducted in shallow lakes of Alaska. From this work we have developed a set of SOPs that will allow maximum data comparability with other agencies and organizations working in Alaska, and will provide accurate data that can be collected repeatedly and are logistically feasible.

An extensive review of literature revealed that little work has been conducted on shallow lakes in the boreal forest, and surprisingly little is known about shallow lake ecosystems in Alaska. The work that has been done typically reported incomplete methodology or used methods that are inappropriate to the broad-scale and remote nature of the CSKN vital signs monitoring project. Because of these factors, we were required to combine elements of multiple study designs into a model we felt best suited the logistic and budgetary restraints of the program, yet maintained scientific integrity.

In 2004, we initiated a second cooperative agreement to help us create an integrated water quality monitoring program. We established a contract with Dr. Dave Verbyla with the University of Alaska Fairbanks to determine which remote sensing platform would best track changes in water quantity across the landscape, conduct a retrospective analysis of water quantity using aerial photographs and Landsat7 imagery, and establish a protocol for annually acquiring and processing imagery on a network-wide basis. This contract was designed to help us monitor water quantity on a network-wide basis.

Measurable Objectives

The Shallow Lake and Pond Limnology Monitoring Protocol of the CAKN Vital Signs monitoring program has four objectives. This protocol contains SOPs for the following four objectives:

1. Detect decadal-scale trends in the area, distribution, and number of shallow lakes and ponds in Central Alaska Network Parks.
2. Detect decadal-scale trends in the water quality of shallow lakes and ponds in Central Alaska Network Parks.
3. Detect decadal-scale trends in the structure and composition of vegetation in shallow lakes and ponds in Central Alaska Network Parks.
4. Detect decadal-scale trends in macroinvertebrate taxa richness and relative abundance in shallow lakes and ponds in Central Alaska Network Parks.

II Sampling Design

Rationale for Selecting this Sampling Design over Others

Many different sampling strategies have been employed to monitor lake ecosystems throughout the world. Most frequently used lake monitoring programs are geared toward understanding the dynamics of a specific lake and typically these studies are designed to evaluate the effects of human perturbation. Monitored lakes are often selected because of their proximity and importance to humans. Many lakes throughout the United States are monitored in this way by state, regional and federal agencies. In Alaska, scientists have been monitoring Toolik Lake since 1975 and more than 200 publications and theses have been written on this lake. This intense level of research has contributed greatly to our understanding of deep lake dynamics in the Arctic. However, these studies have a limited scope of inference to shallow lakes. Several studies have also been done on large lakes in the Matanuska and Susitna Borough. These are focused at identifying effects of specific human actions on particular portions of the lakes. There again, the methods used are of limited utility either on small shallow lakes or on a broad-scale program in remote areas. To the degree feasible, however, the methods used by State researchers have been considered in selection of methods for the CAKN Vital Signs monitoring program.

Spatial extent over which lakes vary coherently among years is poorly understood (Magnuson 1990). Magnuson et al. (1990) showed that several variables including ice cover, water level, and water temperature are linked to climate change and that lakes within a limited range experienced temporal synchronicity. However, our pilot research indicates a high degree of heterogeneity among lakes of close proximity. This is likely due to the patchy nature of permafrost throughout the pilot region and the high variability of lake openness within large flat landscapes. To overcome these issues we believe it is essential that our sampling strategy allows us to understand the variability among lake ecosystems within the network. A limited number of monitoring programs have focused on comparing large numbers of lakes sampled over short periods of time to help understand ecosystem processes. The limitation of these studies is that they are snapshots of time and do not account for intra- or inter-annual variation within a given study area.

Because of the objectives and the interdisciplinary nature of this project, we have developed a sampling design that combines these two monitoring strategies. Each lake selected for *in-situ* monitoring will be assessed for the following vital signs: vegetation, macroinvertebrates, water quality and associated ancillary data (e.g., water level). These vital signs will be monitored during one index time period on each sampling occasion. Only one sample site per lake will be monitored and at one index location (be it transect or sampling station); no composite sampling will be conducted. This strategy will help conserve time and resources on each lake in order to allow sampling on more lakes. The number of samples that would need to be collected to characterize an entire lake would depend on the lake size and many other conditions. This leads to a complex sampling scheme, many samples to be collected, and much more time needed to move about the lake from point to point – first to assess variation and determine appropriate sampling points, and then to collect the samples. While such an effort may be worthwhile on a monitoring program that was focused on a single or few lakes, the additional information garnered would be beyond the needs of the broad-scale monitoring program we are developing. A rough assessment of within-lake variation on all the lakes in the network is obtained from the Within-Lake replication method outlined below.

This strategy allows us to sample a large number of lakes across the landscape however it reduces our ability to monitor detailed interactions and phenological changes that occur within a given lake. To better understand diurnal and seasonal fluctuations in water quality we will also deploy a small (<6) set of multi-parameter probes to continuously monitor the four core water quality parameters (temperature, dissolved oxygen, pH, and specific conductance) throughout the open water season. These probes will be deployed in easily accessed lakes within each of the parks. These data will provide us with essential baseline information on fluctuations in water quality throughout the season. This will provide us with estimates of inter and intra-annual variation and allow us to make inferences to shallow lakes in the entire network.

The sampling design described is consistent - to the degree feasible - with the limited information available on other lake water quality sampling and monitoring projects around Alaska. The few monitoring projects that have been conducted are on large lakes. The shallow depth and small size anticipated under this monitoring protocol require some modifications in, for instance, the sampling depth. Also, the extensive nature of this program and the remoteness of the sampling sites preclude the use of some of the more time and equipment-intensive procedures used in existing programs. Furthermore, we have designed the in-situ monitoring methods to balance ease of use with precision and the ability to detect change. Methods that are simple and easy to use allow quicker data collection and the ability to sample more sites than methods that may be more precise, but effort-intensive. Ease of use is necessary in order to meet Objective 1 of the CAKN Inventory and Monitoring Program (MacCluskie and Oakley 2003), which requires collecting information on a large number of lakes over a broad area. Precision is necessary to detect and isolate ecological changes through time; however, an optimization of the two is necessary to detect temporal variation. Detection power that may be compromised by using less precise methods is often more than made up for in ecological system characterization by the increased sample sizes that are possible with faster, less expensive methods.

Lake Population Being Monitored

Physical, chemical and biological monitoring will be limited to a subset of shallow (<5m deep) lakes and ponds larger than 1 hectare and smaller than 50 hectares in all three parks. Monitoring objectives related to remote sensing will be limited to closed-basin water bodies with an area of less than 50 hectares. A water body of 1 hectare can be resolved on satellite imagery, and therefore we define that as the minimum size of our shallow lake population. Lakes must be closed-basin with no inlet or outlet stream. This criterion eliminates water areas that would be substantially influenced by factors other than long-term climatic trends such as construction or elimination of beaver dams.

The physical, chemical and biologic sampling will be limited to the open water season and will include lakes or groups of lakes that are randomly selected from the sampling frame.

Pond and Lake Frame Construction

Satellite radar imagery (RadarSat 2) will be obtained for all parts of all parks in the CAKN with assistance from scientists at the University of Alaska, Fairbanks. The basic imagery is freely available from NASA, but will require processing and storage costs. Imagery of any particular location in a park is available twice weekly when the satellites involved make their overpasses.

Prior to the first field season, applicable radar images will be compiled into a complete coverage of all parks, and processed to identify individual water bodies, their sizes, and their location. This processing will be automated and easily repeatable in future years if necessary. Following identification of water bodies in the satellite imagery, primary investigators will identify all navigable waters in the list. Navigable waters will include rivers and streams navigable by motorized boats and rafts, as well as ponds and lakes that are large enough to permit float plane landings and take offs. Following identification of navigable waters, all other water bodies will be attributed by distance to nearest navigable body.

Bi-weekly satellite imagery will also be used to identify spring break up in the parks. Break-up, in addition to being of interest itself, will define the time of year that lakes and ponds are sampled in the field.

Lake Selection

The overall sample design for the pond and lake monitoring study will select an un-equal probability sample of ponds and lakes based on distance from navigable water. The probability of including a pond or lake in the overall sample will be inversely proportional to its distance from the nearest navigable water. This design was chosen because of the high costs of traveling to a particular water body on foot after arrival at the closest navigable water body. Because of the time and effort required to haul personnel and equipment into sample units by foot, overall expenses will be reduced if more lakes and ponds are sampled near navigable waters than farther away. Properly weighted estimates based on data from the un-equal probability sample will apply to all water bodies in the sample frame.

The un-equal probability sample will be drawn in a way that assures a high degree of spatial balance. Spatial balance means that sampled ponds and lakes will be spread out approximately uniformly throughout each park. Spatial balance will be achieved by drawing an un-equal probability general randomized tessellation stratified (GRTS) sample (Stevens and Olsen 2004). GRTS samples assure spatial balance by recursively subdividing the parks, drawing the sample, and then reversing the ordering. The final result is a list of ponds and lakes such that any contiguous set achieve have a high degree of spatial balance.

Prior to selection of the GRTS scheme, a few (< 6) ponds will be selected by principal investigators for sampling every summer. These ponds will be located close to easily navigable waters and will serve as index sites for the broader GRTS sample. These ponds will be placed in panel 1 of the pond and lake sampling study, and will not be available for selection in the GRTS sample.

Once the index sites are determined and the un-equal probability GRTS sample is drawn, the pond and lakes membership design will allocate units to panels in groups from the ordered GRTS sample. If n_2 units are required in the 2nd panel, the first n_2 units in the ordered GRTS sample will be assigned to panel 2. If n_3 units are required in panel 3, units from the (n_2 + 1)-th to the (n_2 + n_3)-th in the ordered GRTS sample will be allocated to panel 3. If n_4 units are required in panel 4, units from the (n_2 + n_3 + 1)-th to the (n_2 + n_3 + n_4)-th will be allocated to panel 4, and so on. This membership design will assure a high degree of spatial balance in each panel.

The rotation design proposed for the pond and lake study will be [1-0, 2-8]. Under this rotation design, ponds and lakes in panel 1 will be sampled every year. Ponds and lakes in panels 2 through 11 will be sampled for two consecutive years, then not visited for 8 years, before being sampled again for 2 consecutive years. Rotation of field sampling effort among ponds in panels 2 through 11 would continue indefinitely, or until the frame is reconstructed from new satellite imagery in the distant future.

Sample Location Selection

Within each lake we will be using a set of permanent transects and water quality monitoring stations to assess the condition of shallow lakes. Procedures for locating sampling transect and monitoring stations within a selected lake are described in SOP 13: Installing Benchmark and Establishing Sampling Transect. The approach selected focuses sampling effort in most lakes to one transect extending from the deepest part of the lake to the reach of vegetation most typical of the shoreline of the lake in question. If a lake has multiple distinct shoreline vegetation assemblages, additional transects may be established for monitoring vegetation and macroinvertebrates.

Sampling Frequency and Replication

General

Water quantity will be monitored annually using RadarSat2 images. Each year lake surface area for all CAKN lakes will be calculated from remote satellite images.

Field sampling frequency and replication depends on the sampling frame a pond or lake is assigned. Ponds and lakes in panel 1 will be sampled every year and be monitored continuously throughout the entire open water season for the four core parameters (temperature, dissolved oxygen, pH and specific conductance). Data collected from these sites will be used to help understand inter and intra-annual variation in water quality. Ponds and lakes in panel 2 will be sampled using the synoptic sampling techniques detailed in the methods section. These lakes will be monitored for two consecutive years, followed by 8 years during which that specific lake would not be sampled, making a 10 year cycle for the majority of the lakes. The number of lakes sampled each year will be most dependent on the cost of sampling. This portion of the protocol is still being developed and will be modified after the CAKN overall sampling strategy has been determined.

Within Lake Replication

The inclusion of sampling replication can increase our understanding of variability in water quality data introduced by the field crew and methodology. An additional layer of replication can increase understanding of the variability inherent in the lakes themselves. Field replication will consist of repeat-sampling in one lake in ten. The lake(s) selected as sampling replicates will be randomly chosen prior to the field trip. The same crew members shall do both samplings. Both samplings should occur consecutively within an hour or two. These "field replicates" will indicate the variability associated with sampling methods.

In addition, water quality on one in twenty lakes (5 percent) will be consecutively sampled by each person on the field crew on the same day. This will help to establish variability caused by differences among sampling personnel. These samples will be called "crew replicates." Ten percent of the lakes to be sampled on the trip will be randomly chosen at the beginning of the trip when the lakes to be sampled are selected. Half of those ten percent (i.e. five percent), or at least two, may be used for the crew replicates. The lake(s) actually sampled will be the field crew's choice and may be a function of time allowed, accessibility, weather conditions, etc. *Note that this is not a test of the field crew personnel, but rather an attempt to increase our ability to detect change in actual lake conditions by isolating the variation inherent in having a human sampling crew.*

III Field Methods

High power of detecting change in the system overall is more relevant to the objectives of the CAKN vital signs monitoring program than is the ability to detect change in any particular lake. Most lake monitoring programs are targeted toward monitoring of particular species invasion or some other specific issue. Moreover, they focus on a relatively small number of lakes. Under those circumstances, methods with high precision and low detection limits are important and feasible. However, the enormity of the CAKN lake monitoring project, combined with the general nature of the monitoring objectives, precludes the use of high-intensity methods that provide low detection limits. Therefore, methods were selected that allow fast, inexpensive sampling at a large number of lakes. We prioritize obtaining information on a large number of lakes at the expense of resolution and statistical power to detect small changes in any one lake. The increased sample size that can be obtained with lower-resolution methods is expected to result in higher power detection capabilities in system-wide changes.

Field Season Preparations, Field Schedule and Equipment Setup

Prior to the field season, in April or May, all observers should review the entire protocol, including all of the SOPs paying special attention to SOP 1:, Field Season Preparation, and SOP 9:, Training Personnel. Calibrating all the equipment and reviewing the sampling procedures is critical to maintaining an accurate dataset so it is imperative that each observer successfully complete the training program. The training program will help reduce inter-observer errors to maintain data consistency.

All of the equipment and supplies listed in SOP 10:, Field Trip Mobilization should be organized and made ready for the field season, and copies of the field data forms in Appendix A should be made on all-weather paper. To obtain as complete a data set as possible, it is essential that adequate field equipment and supplies are available for the duration of each field trip. Therefore, extra supplies of all consumables will be packed for each trip.

Before each field season, lakes should be selected, and the time, date and logistics for sampling should be arranged including all park compliance. Two to three lakes should be scheduled for sampling each field day depending upon their proximity to one another. Personnel workloads, weather and forest fires require a somewhat flexible schedule. However, when revisiting a site, it is important to resample the lakes in the same order and on approximately the same day and time the lake was first sampled. This will help reduce diurnal and interannual variation within the data. The timing for sampling can be found in SOP 13:, Installing Benchmark and Establishing Sampling Transect. Field trips should be limited to fewer than 12 days to maintain the integrity of the water samples. Many of the chemical analytes for water have hold times that restrict the length of field trips unless arrangements can be made for samples to be transported to the analytical laboratory.

We expect that the first visit to each lake will require up to eight hours to complete the location and marking of benchmarks and transects and for the initial sampling. Subsequent sampling events can probably be completed in less than four hours. More time should be allowed at the beginning of the sampling season while the field crew familiarizes themselves with the routine and works out any unforeseen problems in the procedures and equipment. The number of lakes that can be sampled in one day will be dependent on their proximity to roads or rivers and to one another. Weather and the potential transportation modes and availability are substantial limitations in the CAKN.

Field Trip Preparation (Mobilization)

Field trip mobilization procedures are given in SOP 10:, Field Trip Mobilization. Field preparation entails assembling gear and making sure field gear is in good working order; assembling sample supplies; creating sample labels; preparing sample materials; preparing field data forms; preparing data recorder for data entry; setting up database for upcoming data; preparing field transportation and camping support for field crews; etc. Lakes to be monitored and a sampling plan must be established, along with contingency plans for poor weather or other confounding factors that arise.

Data/Sample Collection

General

Each night, the group will discuss the next day's plans and establish the route for visiting sampling lakes. Each field day, the procedures of SOP 11:, Daily Field Startup, will be followed prior to sampling the first lake. The lake sampling crew then travels to the first lake each day and follows the sequence of lakes established the night before.

Upon arrival at the lake to be sampled, the crew will determine whether a sampling location has already been located for that lake and whether the GPS will be usable. The sampling location for each lake will be identified during the initial survey (see SOP 13: Installing Benchmark and Establishing Sampling Transect). The location will be recorded using a GPS receiver (see SOP 12: Using the Trimble GPS and the sampling location will also be surveyed back to a permanent reference benchmark on shore as a backup method for subsequent monitoring events. Subsequent water quality sampling occurs at the same location, using the GPS coordinates or by surveying from the established benchmark.

If no sampling location has been established, the procedures of SOP 13: Installing Benchmark and Establishing Sampling Transect will be followed. If the water quality sampling location has not been identified, one person will canvas the lake using the inflatable boat and a hand-held fathometer to locate the deepest part. A temporary buoy may be anchored at the site to aid in relocation for the water quality sampling. Meanwhile, the other crew members will prepare and label field sample bottles and other equipment and begin filling out the field data form. When the sampling location has been determined, all field crew members will work together to establish the GPS coordinates, survey the appropriate sampling transect, and install a benchmark in a location that is likely to remain undisturbed and that will be easy to find in subsequent visits. (Note that these visits may be several years apart, so the benchmarking method must be robust and findable.) Bedrock or a very large rock is a substrate preferable to soil, due to its stability, and will be used if available. See SOP 13:, Installing Benchmark and Establishing Sampling Transect.

The established benchmark will ideally also be usable as a photo point. If it is not, then appropriate photopoints must also be established, marked, and documented. The GPS coordinates of these are also recorded, along with the distance and azimuth from the benchmark, on the field data form for that site. Photograph the lake from each photopoint, documenting the photo ID numbers, photopoint, and subject matter. The compass bearing of the camera would also be helpful. Photos should include the lake riparian area. Inclusion of distant terrain features that will aid in relocation of the photopoint, is also desirable.

Before leaving the field site, ensure there are no contaminating pieces of vegetation on the boat, personnel, or any sampling equipment. Humans are the most effective spreaders of vegetation (and biological) contamination due to our mobility. We must be especially conscientious about not spreading noxious and invasive, non-native vegetation among lakes of the parks. Therefore, a decontamination procedure will be followed prior to moving from one lake to the next or to returning to base camp.

Water Level

In this study, an Abney level, which is hand-held, will be used to take readings from a survey rod to measure water elevation. A compass and optical rangefinder will be used as backup to the GPS to record the horizontal position of the lake water edge relative to the benchmark. This method requires two people, one using the Abney level, compass, and rangefinder and taking notes, the other moving the survey rod and holding at the benchmark, the lake shore, and any needed turning points in between. The relative lake level is calculated by subtracting the survey rod reading on the benchmark (which should always be higher than the lake shore) from the survey rod reading at the water's edge. See SOP 14: Relocating Lake and Sampling Locations.

Water Chemistry

Water quality sampling will occur over the deepest location in the lake. The deepest location can be found in these shallow ponds by traversing the lake in a small boat and determining the deepest location by visual observation or by probing depths with a survey rod or depth line. The location need not be extremely precise, but should be the last area to become exposed should the pond go dry. If in subsequent surveys the established sampling location is clearly not the deepest lake location, sample at the previously-established point and note the location and depth of the deeper location. The difference may be caused by inaccuracies in the location instruments or they could be caused by changes in the lake itself. Notes should be included regarding any indications of the latter; such changes will be an important indicator of conditions or natural variability in the lakes.

Although many ponds will be shallow enough to sample by wading, it is important that some form of boat be used in order to avoid disturbing the lake bed and distorting the water quality readings. Most shallow lakes will be bedded in fine sediments that are easily entrained in the water column. Once entrained, they can take a very long time to settle, greatly increasing the sampling time at each lake. In very small and shallow ponds, it may even be desirable for someone on shore to pull the water quality sampling person into position in order to avoid disturbing sediments by polling or paddling. (*For safety reasons, these ropes must NEVER be affixed to a person!*) Once at the sampling location, an anchor should be gently lowered to hold the boat in position while sampling occurs. Again, minimal disturbance of the bottom sediments is important.

Samples will be collected from 0.5 meter below the water surface. If the lake is less than one meter deep at the sampling location, the sample will be collected from mid-depth. In both cases, the total depth and the sampled depth (measured from the water surface) will be recorded. Samples are collected and recorded in the field form in accordance with SOP 17:, Water Chemistry Field Data and Sample Collection.

Ten water quality parameters will be monitored under this protocol:

- Conventional Water Quality Parameters
- Nitrate/Nitrite
- Total Kjeldahl Nitrogen
- Phosphorous
- Chlorophyll a)
- Alkalinity

- Clarity
- Color
- Dissolved Organic Carbon
- Hardness.

Before leaving the field site, data sheets will be checked for completeness and readability. Data sheets will be checked by a different field crew member than the one who filled it out. That person marks each page "checked", with their initials and the date.

Vegetation

Mapping includes sketching areas of emergent vegetation onto a prepared map of each lake. Sketching should be quick and general. The object of this method is to detect large changes in vegetation patterns; it is not intended to have enough resolution to detect small changes. Mapping may be done by walking the perimeter of the lake, from a vantage point where the entire lake can be seen, or by paddling the boat around the lake perimeter. Where available, GPS points will be taken to locate boundaries of vegetation types. Large lakes may be mapped using aerial photographs, if available; however, such lakes must always be mapped using that method. Switching methods among sampling years is not allowed. Maps will be scanned and stored in the GIS database for reference over time. If needed, polygons of each vegetation type can be attributed for analysis.

The transect survey begins at the water quality monitoring point. Record the vegetation community in each meter of transect up to the onset of upland vegetation or the watershed divide, which demarcates the transect end. Boundary locations between each vegetation class are determined from the results of this survey. Detailed aquatic vegetation quadrat sampling will occur at the midpoint of each community zone delineated in the transect survey, out to 0.5 meters depth. Plants in each sample are inventoried by species and one plant of each species will be retained for species verification. Plant density, species compositions, and relative abundances are obtained from these samples. Any additional species that are observed but not collected in the samples will be added to the observed species list and – except in the case of rare plants – collected. Rare plants will be identified, noted, and their locations recorded using GPS.

Mapping of vegetation beds around the lake can be completed as soon as a crew member is available. After the macroinvertebrate sampling, the aquatic portions of the vegetation transect surveys can be completed. Riparian vegetation sampling can be completed at any time. See SOP 18: Vegetation Field Sampling.

Aquatic Macroinvertebrates

Lakes often show a progression or gradient of attached plant types from shore to deeper water which provide a diversity of habitats for macroinvertebrates. An idealized transect for both vegetation and macroinvertebrate sampling would show emergent macrophytes near shore, followed by floating macrophytes, followed in turn by submerged macrophytes. This entire near-shore area of plant life is termed the littoral zone. Transects will be set up perpendicular to the shoreline if possible, in order to sample the maximum amount of habitats in the littoral zone of each lake. In the case of narrow littoral zones, the macroinvertebrate sampling line will be turned obliquely to shore such that the entire width of the littoral zone is still sampled, but that samples will be evenly spaced across it, providing a consistent sampling scheme. Transect location and orientation will be detailed extensively with field notes and photographs.

Macroinvertebrates will be sampled from five locations along the transect. A standard D-net was specified for semi-quantitative sampling which allows comparison of data between sites, and at the same site over time. In order to do this however, sampling must be standardized and conducted in the same manner over time.

The D-net will be used to sweep from the water surface, down through the water column and any aquatic vegetation, to the substrate and back to the surface again. Samples will be rinsed into a collection tray, rinsed in a 500 μ sieve, and collected into sample bottles that will be adequately labeled. Detailed information will be collected for each sample regarding depth, distance from shore, dominant vegetation, and dominant habitat on the field data form. Data on adult insects observed during the sampling will also be recorded.

IV Laboratory Analysis

General

Water, vegetation and macroinvertebrate samples to be processed by labs are tracked on tracking sheets by date sent out and destination, date analyzed and/or date results returned (SOP 18: Vegetation Field Sampling, SOP 19: Aquatic Invertebrate Field Sampling, and SOP 21: Field Processing of Water Samples.. Once data are received they are entered or corrected in the network database.

Water Chemistry

Water samples will be submitted to a professional laboratory for chemical analysis. Methodology is described in SOP 22: Field Trip Demobilization. The following standard methods will be implemented for each chemical analysis:

Nitrate/Nitrite – EPA 353.2Total Kjeldahl Nitrogen –EPA 351.4

Phosphorous – EPA 353.2

Chlorophyll a –Standard Methods 10200H

Dissolved Organic Carbon – EPA 415.1

Vegetation

Plant species vouchers will be verified or determined by staff at the University of Alaska Fairbanks Herbarium.

Aquatic Macroinvertebrates

Macroinvertebrate samples will be submitted to a professional laboratory for taxonomic analysis. Methodology is described in SOP 23:, Macroinvertebrate Processing and Identification. Samples from the field will be logged in and stored until they can be sorted and identified.

V Method Compatibility

Methods used for other monitoring programs in the state of Alaska and nationally were sought and every attempt was made to use compatible methods. However, no monitoring program was identified that had the same subject, objectives, and scale as this one. Therefore, methods used by others with whom data might be shared were adapted to the degree possible for use in this program.

Water Chemistry methods are similar to those used by the state of Alaska Department of Environmental Conservation (DEC) and Department of Fish and Game on studies reported from the Matanuska-Susitna Borough area. Methods could not be exactly mimicked due to transportation, number of lakes to monitor, sizes of lakes monitored, and monitoring objectives. However, these data should be largely compatible with that collected by those state agencies. The methods adopted here are compatible with pilot study data collected to date by CAKN personnel.

No general broad scale vegetation monitoring projects were identified in Alaska with methods that were appropriate to the large number of remote lakes in the CAKN program. Most monitoring is oriented toward location and tracking of specific invasive species and incorporates underwater survey methods, which were deemed undesirable for this program. Selected methods were adapted from monitoring programs overseen by the Washington State Department of Ecology; the USGS and Army Corps of Engineers monitoring of lakes in Wisconsin; the U.S. EPA national monitoring recommendations, and the U.S. Forest Service PACFISH/INFISH program.

Aquatic macroinvertebrate methods were selected that are used by the U.S. Forest in the state of Alaska and will therefore be compatible with the extensive data from that source.

VI Data Management

The project manager will be responsible for the safekeeping and organization of the data sheets and ensuring that data are entered into the database.

<u>Overview of database design</u>

All of the physical, chemical and biological data collected from shallow lakes are housed in an Access database. The database is located on a file server in the Fairbanks office (the local “K” drive) in K:\Inventory_Monitoring_Program\CAKN\General_ProjectsAndData\Pilot_Projects2003\StreamsAndPonds\StreamsAndPonds.mdb; this file path will likely change with full implementation of the CAKN data management plan. This relational database is structured to account for data from both streams and ponds and when opened presents a choice for one or the other. Choosing “ponds” gets you directly to the data related to shallow lakes. The database deals with seven major categories of information: sample identifier, weather conditions, sample location, water quality, macroinvertebrates (both field and lab data), physical and chemical properties of water (both field and lab data), and vegetation. Each record represents a unique sampling event that associates a time, date and lake location. Data enters the database via two possible routes: download of data entered into a PDA in the field or directly into the database after all field collection of data has been completed. Under full implementation of the CAKN data management plan, the database and related files will be backed up and archived to offsite servers.

Data entry, verification and editing

While in the field, data will be entered into a personal digital assistant (PDA) and on all weather data sheets. Each day the PDA is backed up to a backup disk that is stored at base camp in an all weather container and to a second PDA this insures that the most recently collected data is carefully backed up. At the close of a field excursion after all water samples have been safely delivered to the laboratory and the necessary equipment has been stored the crew leader will deliver the PDAs to the data manager and store the data sheets in the project managers filing cabinet in the folder marked “to be entered and verified”. The data manager is responsible for downloading the data into the Access database and verifying the data are accurately stored in the database. Any data that were not entered into the PDA must be hand entered into the Access database shortly after the field season has been completed. Laboratory results from two separate agreements must also be entered into the database. Macroinvertebrate sample identification is completed by Alaska Biological Research Inc. ABR has been provided with a copy of the macroinvertebrate data table where they enter all macroinvertebrate identifications. Upon completion of sample analysis ABR returns the populated database to the data manager who will review the data and verify the entry prior to inclusion in the primary database.

Data verification is an essential part of data collection. It is critical that the data are carefully reviewed prior to leaving the lake. Once all data have been collected the observer who has been recoding data asks a second observer to review the data sheets for completeness. It is this person’s responsibility to inspect the data sheets and fill in any missing data. This is the most important point of data verification as it is the last opportunity to acquire any missing data. Data collection will be verified again at the end of the day after all data have been collected. After the data have been entered into the Access database by the data manager the project manager should verify the data are accurately entered into the database by randomly comparing the data sheets and PDA to the database.

Once the data have been cleaned and properly stored they are ready to export to STORET, an operational system maintained by the United States Environmental Protection Agency actively being populated with water quality data by many governmental agencies and private entities. Data entered into STORET must be accompanied by information on where the sample was taken (latitude, longitude, state, county, Hydrologic Unit Code and a brief site identification), when the sample was gathered, the medium sampled (e.g., water, sediment, fish tissue), and the name of the organization that sponsored the monitoring. In addition, STORET contains information on why the data were gathered; sampling and analytical methods used; the laboratory used to analyze the samples; the quality control checks used when sampling, handling the samples, and analyzing the data; and the personnel responsible for the data. The National Park Service is developing a tool to allow extraction of water quality data from Access databases such that the data may be easily uploaded into STORET. Specific procedures for accomplishing this are in development and will be incorporated into the CAKN data management plan.

Metadata procedures

Metadata describe the attributes of an information bearing object (IBO). IBOs for this project can be in many formats including documents, data sets, and databases, fields within databases, images, or biological collections. Using metadata to accurately account for data is essential because it provides critical information regarding the format of data to people who are interested in interpreting the data. A metadata record for this project includes representations of the content, context, structure, quality, provenance, condition, and other characteristics of an IBO. Metadata for this project is embedded within the Access database. Within the database are brief descriptions of each data field and table. The metadata also describes how each table within the database is related to one another. An FGDC-compliant metadata document will also be produced and maintained as part of CAKN data management. This document will be produced by the project leader with assistance from the network data manager and maintained on the network website as well as the national I&M Program metadata store (NR-GIS).

Data archival procedures

Data will be archived according to the CAKN data management plan and carried out in concert between the network data manager and the project leader.

VII Analysis and Reporting (To Be Developed)

- Recommendations for routine data summaries and statistical analyses to detect change
- Recommended report format with examples of summary tables and figures for annual reporting
- Recommended methods for long-term trend analysis (e.g., every 5 or 10 years)

VIII Personnel Requirements and Training

Roles and Responsibilities:

The project manager will be the lead ecologist for implementing the monitoring protocol, and will be supervised by the Program Coordinator for the Central Alaska Network. The project manager will typically be responsible for implementing the protocol and will work with contractors to insure the completion of all tasks in a timely manner. The project manager will also be responsible for training observers implementing the protocol to collect high quality data that comply with all QA/QC procedures that both the project manager and data manager have outlined. The project manager will be actively involved in data collection, entry, verification and validation, and summary; and together with the data manager will ensure the quality of data archival, security, dissemination and database design.

Qualifications and Training:

The single most critical component to maintaining a good water quality monitoring program is having well trained and competent observers. There are very specific methodologies for collection of water samples and measuring physical, chemical and biologic attributes of aquatic ecosystems. It is essential that observers be properly trained in calibrating and operating all measuring tools.

Training will consist of office/lab training in procedures, equipment, supplies, sample tracking, sample handling, and data management. Once all crew have been trained in lab, training sessions will be conducted at nearby lakes to ensure that all personnel are comfortable with the procedures and that all equipment is working properly. Initial field visits should be to nearby, easily-accessible lakes to facilitate troubleshooting, repairs, and revision of methods (should such be necessary) prior to being dropped in remote locations with little recourse for correction SOP 9: Training Personnel addresses training needs in more detail for each monitoring element.

Crew Size

Three people will be on each field sampling crew. If necessary, sampling can be completed by two people, but the efficiency is greatly reduced. With a larger crew of four or five, multiple elements can be sampled simultaneously, decreasing the time necessary for each lake. However, transportation can be cumbersome in remote areas and the additional time required for transport can quickly outweigh the benefit from the additional personnel.

IX Operational Requirements

Annual Workload and Field Schedule

Shallow lake monitoring will begin early July and extend through mid August. This time period coincides with peak flowering for most vegetation. Sampling efforts will require a two-three person field crew. Field sampling trips will be scheduled in 10 to 14-day increments. This time frame allows adequate time for sampling a minimum of 10 lakes and provides ample time for logistical access while staying within the allowable holding times for all water samples.

Facility and Equipment Needs

Shallow lake monitoring does not require any additional facilities beyond normal office and laboratory space and equipment storage. Chemicals for calibration and preservation must be stored in the appropriate storage container; either in the OSHA certified fumigation hood or the flammables material cabinet in the laboratory. All chemicals and samples will be accompanied by an accurate and updated MSDS sheet.

Startup Costs and Budget

Personnel expenses for field work are based on a crew of three people: an ecologist to conduct sampling, and train and oversee two trained biological technicians. Field costs will vary greatly from year to year depending on the accessibility of lakes, the method of access (motor boat, float plane or helicopter), and the number of lakes to be sampled.

Cost projections for the completion of this project have not yet been calculated largely because the lakes to be sampled have not yet been identified and we have only recently decided on a within lake sampling strategy. Making cost projections at this point are somewhat premature. The pilot expenses were approximately $40K per year. This figure was based on a sampling a series of 10 lakes, at two index time periods, with three replicated for all water chemistry. The lakes sampled were easily accessed using outboard motors and walking so logistical expenses were quite low. Furthermore, we were able to use biotechnicians provided by the park which helped reduce the overall expense of the project. The within lake sampling strategy presented here is been modified somewhat and sampling costs per lake will be reduced dramatically.

X Procedure for Revising the Protocol and Archiving Previous Versions of the Protocol

Over time, revisions to both the Protocol Narrative and to specific Standard Operating Procedures (SOPs) are to be expected. Careful documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in data collection, for appropriate treatment of the data during data summary and analysis, and for tracking important changes in detection and reporting limits for water quality monitoring. The STORET database for each monitoring component contains a field that identifies which version of the protocol was being used when the data were collected.

The rationale for dividing a sampling protocol into a Protocol Narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of the sampling methods, but that does not provide all of the methodological details. The Protocol Narrative will only be revised if major changes are made to the protocol.
- The SOPs, in contrast, are very specific step-by-step instructions for performing a given task. They are expected to be revised more frequently than the protocol narrative.
- When a SOP is revised, in most cases, it will not be necessary to revise the Protocol Narrative to reflect the specific changes made to the SOP.
- All versions of the Protocol Narrative and SOPs will be archived in a Protocol Library.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in SOP 28:, Revising the Protocol. Each SOP contains a Revision History Log that should be filled out each time a SOP is revised to explain why the change was made, and to assign a new Version Number to the revised SOP. The new version of the SOP and/or Protocol Narrative should then be archived in the LTEM Protocol Library under the appropriate folder. It is imperative that before each field season, the latest versions of each document are used in training field personnel and in conducting the subsequent monitoring.

XI References

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Shallow Lake Limnology Monitoring Protocol
Guide to Standard Operating Procedures and Supplemental Materials

Before and After the Field Season

- SOP#1 Field Season Preparation
- SOP#7 Sampling Frame and Lake Selection
- SOP#8 Continuous Lake Monitoring
- SOP#9 Training Personnel
- SOP#10 Field Trip Mobilization
- SOP#14 Relocating Lake and Sampling Locations
- SOP#27 After the Field Season

Remote Sensing

- SOP#2 Delineation of Study Region
- SOP#3 Image Acquisition
- SOP#4 Image Rectification
- SOP#5 Delineation of Shallow Lakes
- SOP#6 Locating Hot Spots of Lake Change

In Lake Sampling

- SOP#11 Daily Field Startup
- SOP#12 Using the Trimble GPS
- SOP#13 Installing Benchmark, and Establishing Sampling Transect
- SOP#14 Relocating Lake and Sampling Locations
- SOP#15 Photo-documentation
- SOP#16 Water Level Determination
- SOP#17 Water Chemistry Field Data and Sample Collection
- SOP#18 Vegetation Sampling
- SOP#19 Aquatic Invertebrate Field Sampling
- SOP#20 Preserving Plant Samples
- SOP#21 Field Processing of Water Samples
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Laboratory Analysis

- SOP#23 Macroinvertebrate Processing and Identification

Data Management, Analysis and Reporting

- SOP#24 Data Management
- SOP#25 Data Analysis (to be developed)
- SOP#26 Reporting (to be developed)
- SOP#28 Revising the Protocol
- SOP#29 Quality Assurance and Quality Control